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ABSTRACT

The admissions process at Massachusetts Institute of Technology (MIT), freshmen year courses, and the Undergraduate Research Opportunities Program (UROP) are discussed. MIT's admissions criteria include the College Board Achievement Test, Scholastic Aptitude Test scores, high school transcripts, essay replies by applicants, letters of recommendation, and interviews with MIT alumni. Faculty members and admissions staff read admissions folders and score the candidate according to the evidence of quality presented. There are no cutoff scores: each applicant is considered on individual merits. In addition to the preparation level of the student, evidence of intellectual persistence and creativity is of interest to the selection committee. Difficulties encountered by freshmen result from deficiencies in academic preparation and difficulties in budgeting time and setting priorities. Additionally, students have trouble undertaking or appreciating conceptual modeling. The UROP allows undergraduates to join faculty members in an inquiry so that they can learn by example the process of seeking answers and assimilating knowledge. The program also fosters meaningful student-faculty relationships and develops student maturity. Comments made by MIT undergraduates about their research education experience are included. (SW)

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Public Hearing

June 23, 1982

"College Admissions and the Transition to Postsecondary Education"

Testimony

National Commission on Excellence in Education

United States Department of Education

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Introduction

I speak to you today as a faculty member. For almost thirteen years I have taught freshmen, sophomores, and juniors at MIT. As a graduate student I was a teaching assistant and a resident undergraduate physics tutor. Besides MIT, I have supervised, lectured to, or met with a lesser number of undergraduates, e.g. at the University of Cambridge (England), at Mt. Holyoke College, at Imperial College (England), at Berkeley, and at Harvard. My comments derive primarily, then, from experience with a narrow category of student: that selected for high quality, winnowed from a much larger number of aspirants by rigorous college admissions processes.

The manners by which I have interacted with undergraduates include formal advising; teaching in the conventional lecture-with-smaller-recitation-section format; teaching in two academic program experiments for underclassmen; conducting a month-long immersion course to cover a subject usually taught in a semester-long format; and leading small topic-targeted seminars. The academic area of subject most often engaged has been freshmen physics.

At the same time as classroom teaching of undergraduates, I have invited them to join as research colleagues in my professional laboratory pursuits. Approximately seventy-five students ranging from freshmen to seniors, and including four high school students, have participated with me, graduate students, and postdoctoral fellows in low temperature, condensed matter physics experiments. The undergraduate participation has been encouraged by the MIT Undergraduate Research Opportunities Program (UROP), whose purpose is to encourage undergraduates and faculty members to pursue intellectual inquiry together. The experience of undergraduate researchers, especially freshmen and sophomores, is relevant to today's hearing.

I do not speak to you today with the careful, objective, thorough statistics and analyses of an educational researcher or an academic administrator. As a toiler in the educational vineyard, this faculty member wishes only to speak of what she sees and of what she feels about that enterprise. My comments today concern the readiness of entering students to engage MIT.

Admissions

MIT's admissions process includes: College Board Achievement Test and S.A.T. scores together with high school transcripts, essay replies by the candidate, letters of recommendation, and candidate interviews with MIT alumni. Faculty members participate in the selection process. They, with admissions office staff, read admissions folders and score the candidate according to the evidence of quality presented. Folders receive two independent readings and scorings, sometimes three. Round-Up week --- all day marathon decision-making days in the admissions office --- the candidate decisions are made. Faculty member readers are welcome to come in during those discussions to participate.

It is usual, I think, to imagine admissions as a process where first a grim-faced, humorless clerk compares the candidate's high school grade point, class rank, and national test scores to secret values enshrined as the cut-off values. In MIT's process, there are no cut-offs. The key to the success of this approach lies in the strong degree of self-selection exercised by applicants. Over 80% of them are in the top 10% of their high school class. Information provided to guidance counselors states that "...each case is decided on its individual merits: a score of 800 does not ensure admission nor does a score below 600 ensure rejection." Scoring outstandingly on the S.A.T. math test did not in fact, guarantee admissions: only 54% of applicants to the Class of 1985 scoring in the 750-800 range were admitted. Perhaps surprising to you, 10% of the applicants scoring as low as the range 550-590 on the S.A.T. math test also were admitted to the Class of 1985.

If not an 800 score, what then was sought in an applicant? As a faculty member, when I read admissions folders in February I always ask myself, "Do I want this student in my classroom next September?" What I mean is, does s/he have what it takes to make it? Along the way to the bachelor's degree, everyone's high school academic preparation base is eventually exhausted. For some people, this is true before they arrive at freshman orientation week. For others, it isn't until fall term of sophomore year. Only at the juncture when the high school base is exhausted does one discover how really prepared or not a student is for college. Does s/he know how to learn? Does s/he have internally motivating reasons to learn?

It isn't just the preparation level of the student which is of interest to me, but also, evidence of intellectual persistence and creativity. From the application documents one tries to judge these, as well as to assess singleness of purpose, and academic toughness.

The freshmen year is a great leveler. Weakly prepared students who have that intangible Something which I call intellectual fibre, may outlast and exceed better prepared students who do not know how to pursue new knowledge, or who emotionally crumple at the first stout challenge to their high school base. It's not that grades, class rank, and national test scores aren't important or meaningful, but they aren't the whole story nor, perhaps, even the most important part of it.

First Semester Freshmen Year

Not long ago, MIT modified its admissions requirement to allow that, instead of having to take either the Chemistry or the Physics College Board Achievement Test, an applicant might take the Biology Achievement Test. This modification was an effort to open up admissions to potential applicants who exhibit qualities desired in MIT students, but who typically have little or poor high school preparation in chemistry and physics. The spread of backgrounds in my fall term physics recitation classroom is broad --- ranging from people who have previously studied from the same text used for the MIT course, to people who have had little or no physics content despite having presented a transcript listing a year of high school physics. Last year 79% of the entering freshmen presenting themselves for our own advanced placement test for first semester physics failed it; many of these students had already taken AP-type high school courses or scored 4 or 5 on the AP test.

A little earlier, MIT introduced a new freshmen chemistry course as an alternative for complying with the core one semester chemistry requirement for the bachelor's degree. The new chemistry course was below our previous core chemistry course in content and in the level of prior knowledge assumed. In fact, its content is largely that Chemistry we once took for granted in the high school preparation of our entering freshmen. Thus, people may now meet the graduation requirement from MIT with the level of chemistry knowledge we used to expect for admissions to MIT.

As for mathematics preparation, despite the on-paper credentials of having seen trigonometric functions before, of having had algebra and geometry, and of having learned about exponentials, the class is ill-prepared to conceptually utilize these in physics recitation. Students confuse areas with perimeters, incorrectly solve d=vt for v, and cannot estimate $\pi(9.8)^{\sqrt{3}}$ without a calculator. I was told by a freshman that the reason a set of measurements made for one of the required lab exercises was 16% deviant from the accepted value was because he only had eight decimal places on his calculator. Even the one third or so of the class who have been exposed to calculus in high school are not facile. Their calculus is almost unuseable because it is learned as memorized operations, not with understanding. A simple change of variable from the ubiquitous unknown, x, which they've used in high school advanced placement calculus, to a common physics symbol for position in space, r, is sufficient for some not to be able to cary out the mathematical operation.

A diagnostic test administered by Professor A.P. French in September 1976 to incoming freshmen (Class of 1980) to investigate their facility with items needed immediately in freshman physics (algebraic simplifications, factoring, one-variable solutions, simple analytic geometry, logs and exponentials) resulted in an average score of 13.7/26 or 53%. His report states that "over half of the students could not give the most significant terms in the expansion $(1 + x)^3$; weakness was conspicuous in trigonometric identities and logarithms; and there was widespread inability to calculate the distance from the origin to a point (x,y,z) of given coordinates."

The majority of freshmen readily comment that the demands of high school, are, with hindsight, low and illsuited to preparing them for college. Besides deficiencies in academic preparation, time management is such an area. Students do not know how to budget their time for a week, or to long-range plan for finals and term papers. Ability to set priorities is another inadequate skill. It is said on our campus that an education is like getting a drink from a firehose. A student must be selective and disciplined about commitments.

Personal responsibility for his/her own education and individual performance is a difficult realization for as many as a third of the freshmen. They must learn to seek out tutoring help, to discover a different textbook from the assigned one, and to attend additional recitation sections for other viewpoints. For a significant number of freshmen, learning how to present homework in a legible and complete fashion --- on time --- is difficult. For others, it is the taking of formal exams and being graded competitively against class average: multi-step conceptual problems involving close reading of a prose paragraph, interpretation of a diagram and symbols, utilization of trigonometry, algebra, geometry, and calculus with the physics concepts have not been encountered before.

Whether the need is to be self-disciplined about time and priorities, to shore up an inadequate high school science/math base, to develop conceptual problem-solving skills, or to develop an effective approach to examinations, the first step in the process for the student is to emotionally confront the need, and second, to devise and implement a plan to do something about it. Both steps are difficult ones for freshmen. The first because it often challenges a self-image of excellence, or confirms the student's most private gnawing fear about his/her readiness for college work. Around the freshmen is a campus-wide support network of faculty and staff freshmen advisors; a squadron of sympathetic upperclassmen who serve as associate advisors; the Undergraduate Academic Support Office (which sponsors a newsletter, offers study skills seminars, monitors the freshmen evaluation system whereby each freshman writes a self evaluation in each course and receives a written evaluation from his/her instructors two times a semester); and widespread sensitivity of other offices, faculty members, and departments to freshmen. This support system softens but does not eliminate the otherwise almost brutal confrontation with college academic demands which each year's cream of high school graduates experiences.

Second Semester Freshmen Year

The first semester of freshman physics is mechanics, i.e. the study of motion, energy, and momentum, with relatively familiar and concrete entities such as billiard balls, pulleys, inclined planes, friction, springs, pendula, projectiles, automobiles, and wind. It is the complexity of the concepts together with the necessity for facility and ease with basic mathematical techniques which challenge the freshmen. The second semester of freshman physics is the study of electricity and magnetism, ie, the study of electrical and magnetic forces, work, and radiation, based on relatively unfamiliar and unsettlingly abstract notions such as charge, field, electrons, atoms, light, and potential. Electricity and magnetism is truly new to the freshman in subject matter, but more importantly, new in its levels of abstraction and utilization of theoretical models for how the world works.

It is conceptual modelling, I find, which students are least prepared to undertake or appreciate. Intellectually and professionally,

it is here that the demarcation exists between the routine and the lofty thought enterprises. I used to think that modelling was difficult for our freshmen because, in fact, it is a difficult enterprise. I forgave their previous training for not including it by convincing myself that the junior high school and high school days were already full, teaching technique and basic content. Now, however, I am less sanguine about the content and technique acquired. In addition, I no longer believe that modelling is difficult. All six year olds, for example, are excellent modellers, and naturals as scientists. Ask one why the sky is blue, leaves flutter down in spirals, caterpillars are hairy, or why the TV screen has snow on it, and you'll get an inventive, crisp, assured explanation, complete with a mental model, e.g. the sky is really an upside down bowl and all bow's are dark-colored and grey-blue-looking from underneath. Leaves go in spirals because the wind isn't blowing them straight. Etc. Now, ask a twenty-six year old. The response might be many things, but I doubt that it will rank with the six year old's for creativity and blithe lack of embarrassment.

Let me illustrate further by borrowing excerpts from a piece by Selma Wasserman which appeared in the New York Times Education Supplement in November, 1981. It is entitled "The Gifted Can't Weigh the Giraffe."

> "I am led into an attractive room in the low, sprawling school --- the 'center' for working with gifted children. A group of nine volunteers, ages 10 to 12, are led in to participate in a demonstration of a 'teaching for thinking' lesson with this guest teacher.... Around the periphery of the room is a large group of teachers who have come to observe teaching strategies that emphasize higher-order cognitive skills. The pupils are reserved; there is some evidence of anxiety. My attempts to establish rapport are not very successful.
> I offer them a provocative question.
> 'How do you suppose birds learn to fly?'
>
> 'What do you mean?' asks Chris.
>
> 'I don't understand what you want us to do,' says Mark, shifting uncomfortably.

'We didn't study birds yet,' says Ann, explaining the lack of response.

The children are clearly troubled.
I make several attempts --- using a variety of different open-ended tasks that have no clear, definite answers --- to tap the creative thinking capabilities of these children, and I hit a dead end every time.
Again and again I encounter responses in which the pupils try to manipulate me into helping them 'get the right answer.' The more I avoid doing this, the tenser they seem. Their dependency, their rigidity, their intolerance for ambiguity, their inability to take cognitive risks, and their anxiety are astonishing.

The pupils I see later that afternoon are representatives of a different group. Although their school has a more benign name for them, they are the low achievers.
'How could you weigh a giraffe?' I begin. They immediately rise to the challenge.

'You put 'em on a bathroom scale,' says Marla.

'Dummy, he ain't gonna fit,' says Benedetto, smiling at his wisdom. 'You gotta put two scales. Put his back feet on one and his front feet on the other.'

.....Then Sam offers, 'I'd get a big truck and fill it with food that giraffes like to eat. Then I'd weigh the truck. Then I'd hide inside of it and call, "Here, giraffe. Here, giraffe." When he got inside, I'd slam the doors and weigh the truck again.'

I am astonished at the difference in the responses of the two groups and even more concerned about the 'single, right answer' orientation of the pupils identified as gifted. I am flabbergasted at their limited personal autonomy and their difficulty with questions that do not call for single, correct answers.

> ....They are crippled by fears of making mistakes, and their anxieties manifest themselves in a variety of stress-related physical symptoms. Because school tasks are largely of the 'single, correct answer' type (e.g., "The sea is made of _____ water"), these children have become gifted lesson learners --- excelling at the lower-order cognitive tasks found in traditional textbook and workbook exercises.
> Unfortunately, the transfer of these lower-level thinking skills to the higher-order tasks of problem solving, creating and imagining , does not occur magically. There is even evidence to suggest that such activities are counterproductive to higher-order functioning. And so we have a group of gifted children who are exceptionally good at the very narrow tasks of finding single, correct answers to the most mundane questions but who lack experience and therefore expertise in more intellectually rigorous, creative work.
>
> .....it might be fair to conclude that our teaching is decreasing their autonomy and is substantially disabling them...."

It takes all of the second semester to cajole 'what if' questions from recitation students and to inject a little light heartedness into the proceedings so that responses and ruminations can be offered without penalty. It is with surprise, then annoyance, and then delight that these seventeen year olds gain self confidence to discover an error in the printed solutions, to encounter a cul-de-sac in a quiz problem unanticipated by the testmaker, to listen sympathetically to a lecturer redoing a conceptual development or derivation s/he has had second thoughts on after the last class, or to accept the existence of spirited, divided opinion amongst the faculty about the quality of this or that textbook or the merit of this or that topic in the syllabus, or the appropriateness and effectiveness of some particular problem on the final exam. Education has never seemed organic to freshmen before. It was dead: packaged, content known, answers secure. The beginnings of intellectual maturity come with realizing that models have good aspects and bad, that models change and that anyone --- including this particular student --- might be the person whose insight will revise or improve them.

Learning as a Profession

Learning how to learn should be the objective of education. Test scores, homework grades, and credits accumulated do not equate to an education. How to teach this principle? One effort at MIT to immerse young learners in an atmosphere coincident to this mindset is the Undergraduate Research Opportunities Program (UROP).

It has had a significant effect on the educational milieu as it is perceived by both MIT students and faculty, and has been described as the most important single development in education at MIT in the past several decades. UROP provides the opportunity for undergraduates to join with faculty members in an inquiry of mutual fascination 1) to teach students by example the process of seeking answers and assimilating knowledge; 2) to foster meaningful student-faculty relationships on several levels, including advising, tutoring, and teaching; and 3) to develop student maturity and self-confidence in both personal and professional dimensions.

Dr. Edwin H. Land, founder of the Polaroid Corporation, delivered a lecture in 1957 entitled The Generation of Greatness. He said of fledgling learners:

> "I believe that each young person is different from any other who has ever lived, as different as his fingerprints; that he could bring into the world a wonderful and a special way of solving problems; that in his special way, he can be great.
>
> But not many undergraduates come through our present educational system retaining this hope. Our young people --- after a very short time --- give up any hope of being individually great. They plan, instead, to be good. They plan to be effective. They plan to do their job. They plan to take their healthy place in the community."

In effect, this is saying something of what Wasserman's words were saying. Young people generally do not plan or expect to be truly great because the educational system they are in guides them away from such aspirations, and perhaps away from such abilities.

Land went on to say,

> "One feels among our young students, that they are honest and honorable and full of ideals; that they come to the door of our universities with the dream of being our colleagues; that if we could provide them intimate leadership there would be no discipline to which they would not subject themselves and no task so arduous in the pursuit of knowledge and science that they would not devote themselves to it."

It is this colleagueship which UROP seeks to offer students. The invitation written on the inside cover of the program's annual directory is straightforward concerning both the openendedness of the opportunity and the expectation of maturity in participants.

> "You are invited to join with faculty members in pursuit of research and development problems of mutual fascination.
>
> ....This is a chance to 'make good' on your private visions of grandeur.
>
> People are prepared to assist you. But you will find that a certain amount of personal footwork is required in order to achieve a satisfying collaboration. Such a collaboration takes mutual negotiation by all parties. Once you make a commitment to an undertaking, you will be expected to conduct yourself responsibly in the enterprise. In spirit, participation is a privilege, not a right. Your experience will be unlike any other you have had in its benefits and rewards. But you will find its expectations and standards commensurately demanding."

The program's most valuable contribution is that it provides ways for undergraduate students to achieve a sense of individual accomplishment and to generate for themselves the excitement of intellectual discovery. Our intent is to provide them the opportunity to inhabit

a very special moral and intellectual universe that is both demanding and rigorous, but also sympathetic. It is the responsibility of our faculty to guide these young people, to encourage their earnestness and drive, but nevertheless to firmly require that they actually fulfill the 'promise and potential' that got them into MIT in the first place.

Conclusion

What MIT undergraduates have written about their research education experience underscores the hunger that these bright, gifted, young people feel for rigorous, expansive, intimate demands on their intellectual talents. As you read some of their comments listed below, I hope you will agree that these young people and the ones coming along after them in elementary, junior high and senior high school are too good to be allowed to be diminished by an educational system that doesn't stretch them.

- I learned not only about astrophysics but about myself as well --- how to think and how to be self-motivated, how to relate to professors and how to participate in a small group effort. I found the experience often painful and confusing, but I gained a great deal from it and received satisfaction from my work as well.

- One of the best things about this project is that it is mine. I have just begun and I will see it through.

- My experience....was quite unlike any course which I might have taken. The experience was more like a partnership in a project than a student-teacher relationship....all motivation came from within rather than from grades.

- I feel that I am learning skills involving decision-making and initiative which are not taught in class and which are ultimately more valuable than information-level knowledge. I feel that the discussions and seminars in the lab are no longer so much for my instruction as for a mutual exchange of ideas. My voluntary commitment, which is large despite a regular academic load, is a result of the satisfaction I receive from the responsibility and personal rewards of the semi-independent status I enjoy with the laboratory.

- Perhaps a lot of my enthusiasm comes from having worked with Dr. Y., who was not afraid of giving a student extensive responsibility in carrying out a project, but yet was there with advice when questions arose. There is a compromise between giving the student complete responsibility without offering much direction, and constantly leading the student so that he gains little from the potential learning process that research can afford. I believe that Dr. Y. was an advisor who was able to maintain that compromise. He was willing to give responsibility, but was also firm in correcting so that the student could improve his skills and knowledge.

- My UROP work was easily the most valuable academic work I've done at MIT.....my general knowledge and understanding of many basic engineering principles grew more naturally and comprehensively than what's possible in regular academic classes. This is especially important to me, because I've found many of my conventional courses frustrating and unrewarding. Largely due to my UROP experience, my attitude toward the rest of my curriculum has been renewed with enthusiasm.

- I feel the insights I gained into the struggling thought behind research will have a much greater long-term effect upon me than the information of the research itself. It seems that exploratory research such as this is where whole new theories are born and it allows for much creativity in the exciting discovery of truly new insights.

- I can say without reservation that my undergraduate research experience has been the most important factor in my intellectual and professional development at MIT. Central to this fact is the time and effort devoted to me by Prof. X. His approach to me and to other undergraduates has been to treat us as equals. While this means that he has demanded a lot from us, it also means that the desire and confidence required to fill those demands has been created.

- But enough, I could write for pages about what I've learned and how it really gave me reason for being here. There is an excitement with this kind of contact with people that makes one feel fulfilled. There aren't too many jobs that are this special, least of all something one can experience freshman year in college. I honestly don't know what to say in appreciation. I OWE too much.

- .....There is a certain dedication, or "spirit" in the group which is most exhilarating and which can't be caught by reading a book. Other things impressed me also--working with people gives one new insights on how to attack problems, seeing others tackle problems I would have approached otherwise; seeing (and feeling the results!) that something sounds good in theory but does not always work in practice; and especially discovering that the amount of time necessary to do a bit of work is significantly greater than estimated.

- .....Z was a great supervisor, and I'd recommend working with him to anyone. He has a real knack for explaining things and making them seem simple. He conveys his interest and excitement in his work to students very well. When I didn't understand something, he explained patiently, and when I was discouraged, he gave me ideas to work on, and the best possible encouragement. He always treated me with respect for my ideas, and made me feel as if I were working with him, not under him. We made decisions together, and he never did anything without telling me why he was doing it.

- . . . progress was slower than I wanted it to be. This was probably the most important lesson I learned during the summer. Research does not proceed by leaps and bounds.

- ...one of the most profitable things I found here was learning to know when to ask for help and where to find it when you need it.

- Self organization is much more necessary in doing research than in the courses. It was a great adjustment for me to not have a reasonably detailed instruction sheet of procedures to be followed. It did not mean so much in deciding what to do as it did in keeping track of what I had done. The writing of a detailed notebook is superfluous if you are following the lab instructions. But if you are making your own way, the procedures must be written up.

- On several occasions I have been asked to do something which I thought was beyond me --- but which I was eventually able to complete. I have learned not to panic.

- Close contact with my supervisor on a real research project was very exciting. Together we would discuss the results, and work out new methods of approach. I had to develop theoretical models to try and explain what was happening and although these were frequently unsuccessful, they called for an effort of imagination and an application of theoretical knowledge quite unlike anything encountered in my classes.

- Probably the one aspect of the research project which taught me the most was my fellow workers. It is incalculable the education they have given me. Just to be around such people of high caliber has an effect on oneself that cannot be measured. They constantly stirred ideas in my mind which added to my interest in the project.

- The magnitude of the responsibility which one must assume as a member of a research group was not fully apparent to me... Little by little...I have realized in a personal way that when I come to do research in a group, I must bring to it all that I have learned (not just time and labor). This was perhaps my hardest lesson.